

**TASK 2 REPORT
SELECTION OF THE
CHEMICALS AND
RADIONUCLIDES
OF CONCERN**

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For:

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EXECUTIVE SUMMARY

In Task 1, ChemRisk identified about 2,500 chemicals that were classified as being of moderate to high toxicity. The objective of Task 2 is to select chemicals and radionuclides that were most likely to have posed an off-site health hazard under historical routine operation of the plant.

ChemRisk identified 5 radioactive elements and their isotopes (12 radionuclides in total) as being those most likely to have posed an off-site health hazard for further study. The selection is based on the quantities of radionuclides present at the Rocky Flats Plant, effluent monitoring data and environmental sampling data.

ChemRisk devised a three-stage process to select chemicals of concern. In Stage 1, well-known environmental toxicants are identified including: carcinogens, chemicals identified by the U.S. EPA as important chronic toxicants and known human reproductive and developmental toxicants. In addition, chemicals with inventory quantities greater than 5 kg are also identified. A total of 629 chemicals are selected in Stage 1 for further screening.

In Stage 2, the toxicologic properties and inventory quantities of the chemicals selected in Stage 1 are evaluated. Chemical release assumptions and screening dispersion models that are likely to overestimate the dose received by the community (conservative models), are used to evaluate the potential of each chemical to pose an off-site health hazard. A total of 46 chemicals are selected in Stage 2 for further screening.

In Stage 3, detailed information on storage locations, annual usage rates, nature of usage, nature of toxicity and environmental fate of the chemicals selected in Stage 2 are reviewed. Based on this individual evaluation of each chemical, a total of 20 industrial chemicals and pesticides and herbicides as a group are identified as having been of potential concern for off-site impacts.

The 5 radioactive elements and their isotopes (12 radionuclides in total), the 20 chemicals and the pesticides/herbicide group will be the subject of further project investigations to evaluate potential historic off-site exposures to these compounds.

1.0 INTRODUCTION

The objective of Task 2 is the selection of those compounds that will be the subject of further study for their historical impact on off-site populations from among the dozens of radionuclides and thousands of chemicals that have been identified as having been present at the Rocky Flats Plant (RFP). It is important to note that this selection process is primarily intended to address the study of chemical and radionuclide releases associated with routine operations at the plant. Accidents and incidents will be identified in the course of the reconstruction of the history of operations at the plant (Task 3). Those accidents or incidents identified as having the potential for posing impacts to off-site populations will become the subject of further study by the project. The investigations of these accidents or incidents will not be limited to those compounds selected by this task, but will include all those compounds of potential concern for the individual event.

The nature of the selection process employed in this task for the radionuclides of concern differs considerably from that used to select the chemicals. The difference stems from the fact that virtually all radionuclides have the potential for posing an impact or contributing to radiation exposure if released in significant quantities while not all chemicals are associated with the same level of concern for potential health impacts. Also, public awareness and concerns are principally focussed on radionuclides since Rocky Flats is a nuclear facility. The radionuclide selection process has therefore focused on the identification of the those isotopes known to have been present in large quantities and used in a manner likely to have resulted in a release to the environment.

As discussed in the Task 1 report, radionuclides have been tracked and inventoried at the plant for the majority of its operating history and have been the subject of extensive monitoring of both emissions and environmental media. The quality of our knowledge regarding the types and relative quantities of radionuclides present at the plant and detected in the environment surrounding the plant is very good. The list of radionuclides handled in large quantities (greater than 1 kilogram)

identified in Task 1 is relatively short. Therefore, an elaborate selection scheme was not deemed necessary to select isotopes for further study, since it is believed that all isotopes having a reasonable potential for posing off-site impacts can be addressed by the project. This report identifies radionuclides believed to fall into that category.

In view of the large number of chemical compounds identified as having been present at the site and the less certain knowledge of the nature of their use and release, a much more elaborate selection scheme is presented in this report for the chemicals. The selection scheme relies on some limited knowledge of the relative quantities of the compounds present at the plant site, as identified by project Task 1, and known intrinsic properties related to the chemical's toxicity.

2.0 SELECTION OF RADIONUCLIDES

The Task 1 report identifies radionuclides that have been present at the plant site, grouping them into three categories:

- Group 1: production related radionuclides handled in kilogram quantities,
- Group 2: research and analytic related radionuclides handled in gram quantities, and
- Group 3: other sources (sealed solids, plated, liquids, and analytic stock solutions).

The list of radionuclides identified in each of these groupings as historically present at the site is reproduced from the Task 1 report in Appendix A. Of the radionuclides present at the plant site, only those falling in Group 1 are likely to be associated with off-site impacts, if any, under normal operating conditions. The Group 1 listing includes those isotopes associated with metal fabrication and assembly and chemical recovery and purification of process-produced transuranic radionuclides. Group 1 includes isotopes of plutonium, enriched uranium, depleted uranium,

natural uranium, uranium-233, and to a lesser degree natural thorium. Americium-241, a decay product of plutonium-241, also occurs in significant quantities. Radionuclides in the other two groupings are present in quantities and physical forms that generally preclude them from being a radiological dose concern to an off-site population.

Effluent monitoring and environmental sampling data were reviewed to establish whether plant related radionuclides other than Group 1 isotopes have been detected. The documents identified in Appendix B were reviewed for this purpose. With the exception of tritium, monitoring data are consistent with the release of only Group 1 compounds from the facility. Tritium has been detected in plant effluents and in off-site environmental media. Tritium was also associated with a release incident in 1973.

The plant effluent data indicate the presence of most of the primary production radionuclides (Group 1). The radionuclides detected include plutonium-238, 239, and 240; uranium-233, 234, and 238; americium-241; and tritium. Effluent sampling does not routinely include plutonium 241 and 242, uranium-235, and thorium-232 for a number of reasons. Plutonium 241 is a beta emitter and as such is a small dose contributor relative to the other plutonium isotopes. Plutonium 242 is present in small quantities relative to the other plutonium isotopes. In enriched uranium, uranium-235 is present at levels above the approximate 0.7% by weight found in naturally occurring uranium, however the uranium-234 isotope usually accounts for a great majority of total alpha radioactivity. Thorium-232 is not used in significant quantities relative to other production radionuclides.

Environmental sampling data indicate the presence of isotopes of plutonium and uranium, americium-241 and tritium. These radionuclides appear in measurable quantities in some samples of ambient air, water, soil, and vegetation. Plutonium concentrations in the immediate vicinity of the plant are reported to be higher than normal environmental levels. Detectable quantities of other

radionuclides characteristic of nuclear weapons fallout, such as strontium-89 and 90, zirconium-95, cesium-137, and cerium-144 were also found in environmental samples from 1970 through 1981. Detection of these compounds is consistent with the presence of fission products from worldwide fallout and the detected levels are typical of other sites sampled in the western United States.

The radionuclides that will be the subject of further study have been selected based on:

- Known relative quantities of radionuclides present at the Rocky Flats Plant,
- Effluent monitoring data, and
- Environmental sampling data.

Those radionuclides present in sufficient quantity and used in such a manner that they have the potential to impact off-site populations or have been detected in effluents or environmental media include:

- Americium - 241,
- Plutonium - 238, 239, 240, 241, and 242,
- Thorium - 232,
- Uranium - 233, 234, 235, and 238, and
- Hydrogen - 3 (tritium).

These radionuclides and their significant decay products will be the subject of further project investigations related to normal operations. Accidents or incidents that are selected for study by the project will be evaluated separately and will not necessarily be limited to these radionuclides.

3.0 SELECTION OF CHEMICALS

The Task 2 plan identified two methods for the selection of chemicals of concern. The first method is a qualitative approach employing experts to review the available information and take public concerns into account in the identification of those compounds that should be the subject of further study. The second method is quantitative in nature, employing a formal selection scheme for identifying the chemicals of concern. The qualitative evaluation and general review are being performed by individuals on the Rocky Flats Health Advisory Panel (HAP) and by other experts selected by the HAP. The results of these activities are not part of this report. This report describes the quantitative process employed by ChemRisk to identify those chemicals that are recommended for further study by the project.

The Task 1 report presented the first step of the selection scheme by grouping the chemicals that have been present at the plant site into three categories:

- Group 1: those chemicals that should be subjected to formal evaluation to identify the chemicals of concern (Priority 1),
- Group 2: trade name products (Priority 2), and
- Group 3: those trade name products or substances that are believed to have little or no potential for posing an off-site health hazard (Priority 3).

There are two lists within each grouping. The first list is those chemicals and their quantities found on the 1988/89 inventory. The first list also identifies quantities for those chemical that were also on the 1974 inventory. The second list is those chemicals that are unique to the 1974 inventory. The lists associated with each grouping were presented in Appendices A-C of the Task 1 report.

As discussed in the Task 1 report, there are two primary sources for the listing of the chemicals used at the Rocky Flats Plant (RFP). The first is a computer database containing one of the latest Rocky Flats Chemical Inventory Lists obtained from the Environmental Restoration and Waste Management Group at Rocky Flats. This list is an updated version of the 1988/89 Chemical Inventory List on file in the Rocky Flats Public Reading Room. The second is a chemical inventory prepared by Dow Chemical Company in January, 1974. The Dow inventory represents a compilation of separate inventories conducted in all the plant areas.

In addition to these inventories, information regarding annual consumption rates was obtained from the April 1980 Final Environmental Impact Statement (EIS) for the plant. Although the EIS contains information for only a handful of chemicals, it provides information on the relationship between inventory quantities and chemical usage at the RFP. Finally, information from the three reports identified in Task 1 that identify chemicals present in environmental media and that are the subject of clean-up efforts was also used for the purpose of the selection process.

The sources of toxicologic information used in the chemical selection process include the following:

- Slope factors (SF) for carcinogens and reference doses (RfD) for noncarcinogens are obtained from the Health Effects Assessment Summary Tables (HEAST)(U.S. EPA, 1990a) or the Integrated Risk Information System (IRIS)(U.S. EPA, 1990b). The SF, which is expressed in units of $(\text{mg/kg-day})^{-1}$, is the 95 percent upper confidence limit of the probability of carcinogenic response per unit daily intake of a chemical over a lifetime. A RfD, as defined by the U.S. EPA, is the dose (mg/kg-day) of a chemical that is not expected to cause adverse health effects over a lifetime of daily exposure.
- Reproductive and developmental toxicants are identified by reference to those listed under the California Safe Drinking Water and Toxic Enforcement Act (also known as Proposition 65) (CHWA, 1990) and the Catalog of Teratogenic Agents (Shepard, 1989).
- Oral LD_{50} and other general toxicological information are obtained from the National Library of Medicine's electronic databases: Registry of Toxic Effects of Chemical Substances (RTECS) and Hazardous Substances Data Bank (HSDB). If no toxicological information for a chemical is found in either of these databases, Dangerous Properties of Industrial Material (Sax, 1989) is also used.

3.1 Overview of the Chemical Selection Process

In Task 1, ChemRisk identified more than 8,000 chemical and product names that have been used at the RFP. Each of these items is assigned to one of three priority lists. The Priority 1 list consists of chemicals that are believed to have the potential to pose an off-site health hazard and require further evaluation. The Priority 2 list is comprised of trade name products and the Priority 3 list consists of substances and trade name products that are believed to have little or no potential for posing an off-site health hazard.

There are approximately 2,500 chemicals on the Priority 1 list. The objective of Task 2 is to select those chemicals that are believed to be the most likely to pose an off-site health hazard. Given the enormity of this task, the selection process is divided into 3 stages to optimize the use of time and resources. Three flow charts are provided in Figures 3-1, 3-2 and 3-3 to describe the screening process that is employed for this purpose. Figure 3-1 provides an overview of the entire chemical identification and selection process under Tasks 1 and 2.

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insert figure 3-1

insert figure 3-2

insert figure 3-3

The purpose of Stage 1 screening (Figure 3-2) is to rapidly select those chemicals that should be the subject of further consideration based on readily available information. First, well-known toxicants, i.e., known or suspected human and animal carcinogens and chemicals with an assigned reference dose (RfD), are identified from the Priority 1 list and assigned to the Hazardous Chemicals List. Secondly, those chemicals that are known to have been released into the environment are identified and assigned to the Hazardous Chemicals List. Thirdly, those chemicals recognized as reproductive or developmental toxicants are identified. Finally, chemicals with inventory quantities in excess of 5 kg are identified from the remaining chemicals on the Priority 1 list and assigned to the Hazardous Chemicals List. Therefore, Stage 1 screening identifies those chemicals believed to be most likely to pose an off-site health hazard based on:

- Qualitative toxicity information, or
- Estimated quantity

The purpose of Stage 2 screening (Figure 3-3) is to make a rough estimate of whether the quantity of a chemical on-site is sufficient to pose an off-site health hazard. To perform this evaluation, quantitative toxicity information was located using various authoritative sources for the chemicals on the Hazardous Chemicals List. Using chemical release and dispersion estimates for drinking water and inhalation exposures that are likely to overestimate contaminant concentrations (conservative estimates), the maximum (or allowable) quantity of a chemical that can be present on-site without potentially posing an off-site health hazard is estimated. The reported inventory quantity of a chemical is then divided by the estimated maximum (or allowable) quantity. If the resulting ratio (quantity ratio) is greater than one, the chemical is assumed to be present in sufficient quantity to potentially pose an off-site health hazard. Conversely, if the quantity ratio is less than one, the chemical is probably not present in sufficient quantity to pose an off-site health hazard.

The purpose of Stage 3 screening is to evaluate chemicals selected in Stage 2 to determine the likelihood of their release to the environment based on their usage, quantity and location within the Rocky Flats facility.

3.2 Consistency of Reported Quantities

The identified screening process relies on toxicity and quantity to select chemicals for further consideration. Manufacturing processes and the usage rate of chemicals at the RFP are likely to have changed over the past 38 years. The quantities reported in the 1974 and 1988/89 inventories are compared in this section with the intent of evaluating the degree of change over time. In addition, inventory quantities are compared with reported annual usage rates for the purposes of evaluating the relationship between inventory and use.

Altogether, a total of 1,020 Priority 1 chemicals are common to both the 1974 and 1988/89 inventories. To compare the quantities on these two inventories, the 1988/89 inventory quantity has been divided by the 1974 inventory quantity for each chemical. A listing of the resulting ratios is presented in Appendix C. Some simple statistics associated with the ratios are helpful in characterizing the variability of the inventory quantities. The mean value of these ratios is 15, suggesting that, on average, the quantities in the 1988/89 inventory are fifteen times higher than those on the 1974 inventory. However, the standard deviation of the ratios is 326, suggesting that there is a very wide range of ratios, making broad generalizations about the quantity comparison difficult. There are many possible sources of differences in the reported quantities in the two inventories, including:

- Differences in the inventory methods,
- General change in facility size and production rates,

- Changes in production processes, or
- Trends in chemical substitution.

Figure 3-4 graphically summarizes the result of these quantity comparisons. As shown in the figure, 9% of the chemicals have almost identical inventory quantities and about 72% of the chemicals have a ratio between 0.1 and 10 (i.e., within an order of magnitude). About 19% of the chemicals have a ratio less than 0.1 or greater than 10. This comparison illustrates that while the reported inventory quantities of the Priority 1 chemicals at the RFP in 1974 and 1988/89 vary considerably, the majority differ by an order of magnitude or less.

As will be discussed further in Section 3.3.2, an estimate of the annual usage rate of each chemical is needed to evaluate the likelihood of a chemical posing a potential off-site health hazard. To calculate the potential relationship between the inventory quantity and annual use rates, the 1977 annual usage rates of 30 chemicals as reported in the 1980 Final Environmental Impact Statement are compared with the 1974 and 1988/89 inventory quantities. The result of these comparisons is summarized in Table 3-1. Out of the 50 comparisons, there are 8 instances where the ratios are substantially greater than 10, and 3 instances where the ratios lie between 10 and 15. In all other cases the ratio is 10 or less. Based on this limited comparison between annual usage rates and inventory quantities, a general assumption that the inventory quantity of a chemical represents approximately 10% of its annual usage is made for the purpose of the selection process.

3.3 Implementation of the Screening Process

The following sections describe in detail the three screening stages performed in this task. It is important to note that some modifications were made in the screening process

insert Figure 3-4

insert table 3-1

outlined in the Task 2 Plan. These modifications have resulted in a streamlining of the screening process. It is also important to note that two groups of chemicals were taken side-by-side through the screening process. The first group is those chemicals that appear on the 1988/89 inventory. In the event that a chemical is also listed on the 1974 inventory, the larger of the two inventory quantities was used when chemicals appeared on both lists. The second group is those chemicals that are unique to the 1974 inventory.

It also should be noted that numerous spelling and/or syntax errors are present in the 1988/89 and 1974 inventories, and some chemicals have been entered into the database under more than one synonym. In these cases, errors have been corrected and the quantities for individual entries are summed prior to Stage 1 screening. A complete record of which inventory quantities have been summed is presented in Appendix D.

In implementing the screening process, the following modifications to the Task Plan were made:

- The list of chemicals was divided into 3 priority groups as part of Task 1.
- To estimate the allowable quantity of a chemical for Stage 2 screening, it was necessary to locate some information regarding the toxicity of each chemical. In Task 1, approximately 2,500 chemicals were classified under Priority 1. For some chemicals, the quantitative toxicity information is not readily available or non-existent. U.S. EPA's Health Effects Assessment Summary Tables (HEAST) (USEPA, 1990a) are used as the sole information source to identify those Priority 1 chemicals with an established RfD or SF. A more thorough search of the available literature for toxicity information (e.g., oral LD₅₀s) was undertaken for those chemicals with an inventory quantity in excess of 5 kg. Based on the release and dispersion models described in greater detail in Section 3.3.2.3, it is estimated that a highly toxic chemical with an inventory quantity of 5 kg or less is not likely to pose an off-site health hazard.
- Based on the results of Stage 2 screening, it is estimated that 46 chemicals could pose a potential health risk to off-site individuals under either drinking water or inhalation exposure scenarios. Stage 3 screening, as proposed in the task plan, was not pursued since it is felt that the proposed quantitative ranking would imply greater precision in the selection process than the available information could support. Instead, a modified Stage 3 screening process is employed to further evaluate the chemicals identified in Stage 2.

3.3.1 Stage 1 Screening

As described above, the purpose of Stage 1 is to rapidly identify those chemicals that can be removed from further consideration using readily available information. This section provides a detailed description of the steps taken to implement Stage 1.

3.3.1.1 Evaluation of Priority 2 List

The Task 1 report identified a large number of trade name products that were classified as Priority 2 substances. An initial effort was made to identify the individual constituents of Priority 2 substances having the greatest inventory quantities, e.g., those with 1988/89 inventory quantities greater than approximately 30 kg. The primary source of information was Material Safety Data Sheets (MSDSs) supplied to the RFP by the manufacturers. In addition, a chemical list produced during a revision of the RFP Hazardous Materials Manual in 1975 includes some information regarding the constituents of trade name products. No attempt was made to determine the composition of trade name products appearing only on the 1974 inventory since the availability of MSDSs for that period was expected to be limited.

The quality of information regarding chemical constituents of trade name products varies widely. In most cases, however, the major constituent(s) and the percent composition can be identified. The quantity of each product constituent (i.e., the quantity of the substance in the inventory multiplied by the percentage of that constituent in the substance) can generally be established using information provided in the MSDS. When chemicals identified as being present in products on the Priority 2 List were already listed as Priority 1, the chemical quantity associated with the product was added to the Priority 1 inventory quantity. If the chemical constituent was not already listed on the inventory, it was classified as a Priority 1 or 3 chemical (as described in Task 1) and added

to the appropriate list. The revised quantity for each Priority 1 chemical is then used in the screening process. Those Priority 2 substances for which only qualitative composition information is available were treated in the following manner:

- If a Priority 2 trade name product contains only one major chemical, it is conservatively assumed that the quantity of the chemical is equal to the quantity of the product.
- If a Priority 2 trade name product contains several constituents, no assumptions were made and no changes were made to the Priority 1 List.

With the exception of two substances, constituent information of all Priority 2 substances with 1988/89 inventory quantities greater than 300 kg was located. The Priority 2 substances for which composition information was identified are presented in Table 3-2.

The above described changes resulted in a Modified Priority 1 list, which was carried through the remainder of Stage 1 of the screening process.

3.3.1.2 Subdivision of Priority 1 Chemicals

The chemicals on the modified Priority 1 list have been placed into the following groups:

- Chemicals with carcinogenic potency slope factors,
- Chemicals with noncarcinogenic reference doses,

insert table 3-2 (a)

insert table 3-2 (b)

- Reproductive and developmental toxicants, and
- Chemicals that are known to have been released into the environment surrounding the RFP.

It should be noted that a chemical can be placed in one or more of the groups listed above. Chemicals placed in any one of these groups become part of the Hazardous Chemicals List and are evaluated in Stage 2. The Reproductive and Developmental Toxicants List is presented in Appendix E.

Based on several remedial investigation reports, it is known that a number of chemicals were detected in the soil or groundwater at RFP. Chlorinated solvents, and metals were detected at the 881 Hillside, East Trenches, 903 Pad and Solar Ponds. Acetone, cyanide and nitrates were also detected at a number of locations. A listing of chemicals detected in the environment can be found in on page 27 and 28 of the Task 1 report.

Most of the chemicals detected in environmental media are included in the Hazardous Chemicals List. A few common ions like: nitrates, calcium, iron, potassium and sodium, are not included. It is believed that even if these ions were released into the environment in significant quantities, they are not likely to pose an off-site health hazard.

Chemicals not falling in one of the four groups identified above are further subdivided as follows:

- Chemicals with 1988/89 and 1974 inventory quantities less than 5 kg are placed on list A (Figure 3-2). Based on the release and dispersion models described in greater detail in Section 3.3.2.3, it is estimated that a highly toxic chemical with an inventory quantity of 5 kg or less is not likely to pose an off-site health hazard. The list A chemicals are presented in Appendix F.
- Those chemicals with 1988/89 or 1974 inventory quantities greater than 5 kg are included in the Hazardous Chemicals List (Figure 3-2).

The complete Hazardous Chemicals List is presented in Appendix G.

3.3.2 Stage 2 Screening

This section provides a detailed description of the steps required to implement the Stage 2 screening of the Hazardous Chemicals List. As with Stage 1, two groups of chemicals, those on the 1988/89 inventory and those unique to the 1974 inventory, were evaluated. For the chemicals on the Hazardous Chemicals List that do not have a SF or RfD, several authoritative sources were searched for available toxicity information (specifically, an oral LD₅₀). Chemicals having no published SF, RfD or oral LD₅₀ values are placed on List B (Figure 3-3) and are presented in Appendix H. Some acids in List B that have large reported inventory quantities are qualitatively evaluated in Stage 3 screening.

3.3.2.1 Adjustments of Chemical Quantities

The bulk of the Stage 2 screening procedure is based on a chemical's toxicity (e.g., slope factor) and its inventory quantity. The toxicity criteria are used to determine an "allowable" quantity, which is then compared to the quantity reported in the inventory. In some cases a single toxicity value, and therefore a single allowable quantity, has been assigned to a group or class of compounds, e.g., those compounds that contain a common element (metal). For example, hexavalent chromium, a known human carcinogen by the inhalation route, occurs in a variety of chromium compounds (e.g., chromic acid, potassium dichromate). Therefore, the allowable quantity calculated based on the hexavalent chromium slope factor should be compared against the total quantity of all hexavalent chromium compounds. Inventory quantities of the following elements were summed prior to comparison with the allowable quantity calculated based on the toxicity of the elemental form:

- arsenic
- barium
- beryllium
- boron
- cadmium
- chromium
- lead
- manganese
- mercury
- nickel
- selenium
- tin

For silver, zinc, and vanadium, the compounds silver cyanide, zinc cyanide and vanadium pentoxide have unique toxicity criteria and were therefore treated separately. All other compounds for these elements were summed and assigned the toxicity of the elemental form. For aluminum, antimony, lithium, and magnesium, there are no toxicity criteria for the elements, rather the toxicity criteria are based on specific compounds. In this case, the toxicity values for specific compounds were used to evaluate the corresponding elemental group. No toxicity criteria were found for sodium and potassium, and the majority of sodium and potassium compounds have individual toxicity criteria. As such, sodium and potassium compounds were treated individually.

There are five other instances where inventory quantities were summed. First, all of the Aroclors were considered together, since the toxicity criteria for Aroclor 1260 is applied to all of them. Similarly the inventories for quantities of all polycyclic aromatic hydrocarbons (PAHs) were summed, and the toxicity for benzo(a)pyrene is used to evaluate the group in Stage 2. Third, there were two entries on the inventory for tetrachloroethane that did not identify the specific isomer. As such, these quantities were conservatively added to the quantity for 1,1,2,2-tetrachloroethane, which is classified as a carcinogen. Fourth, the inventory quantities of hydrazine and hydrazine sulfate were summed. Lastly, a single entry on the inventory, Toluene T-324, was included with the quantity for toluene. The total quantities for each group are presented in Appendix I.

3.3.2.2 Exposure Scenarios

In Stage 2 of the screening process, quantitative toxicity criteria and inventory quantity information are used to predict whether a sufficient quantity of a chemical is likely to be present at the RFP to pose a potential off-site health hazard. This is accomplished by determining the maximum allowable quantity of a chemical that can be present at the site without posing an off-site health hazard based on conservatively designed exposure scenarios. Two exposure scenarios, inhalation of vapors or particulates and ingestion of drinking water, are included in the screening procedure.

3.3.2.2.1 Inhalation Exposure

The maximum allowable quantity of a chemical that can be present at RFP without posing a potential inhalation hazard can be determined in three steps, each of which are described below.

The first step is to calculate the maximum annual average air concentration of a chemical (mg/m^3) that can be inhaled by an off-site individual without adverse health effects. This calculation is based on the maximum allowable lifetime average daily dose as defined by a certain level of risk (carcinogens) or exposure (noncarcinogens).

The maximum allowable lifetime average daily dose for a carcinogen is derived from the carcinogenic potency slope factor (SF) and a defined level of risk. By using the 95 percent upper confidence limit, this estimate of carcinogenic response is conservative in that it usually overestimates the actual risk posed by the chemical. For the purposes of this screening procedure, an excess cancer risk of one in one million (1×10^{-6}) over a lifetime was used as the cut-off point. Using an excess cancer risk of 1×10^{-6} and assuming a SF of $10 \text{ (mg/kg-day)}^{-1}$, the maximum allowable lifetime average daily dose of a carcinogen can be calculated as follows:

$$\begin{aligned}\text{Maximum Allowable Lifetime Average Daily Dose} &= \frac{1 \times 10^{-6}}{10 \text{ (mg/kg-day)}^{-1}} \\ &= 1 \times 10^{-7} \text{ mg/kg-day}\end{aligned}$$

For noncarcinogens, the maximum allowable lifetime average daily dose is simply equal to the reference dose (RfD). When a chemical does not have a RfD, a "derived RfD" can be estimated by multiplying the oral LD₅₀ (mg/kg) of the chemical by a factor of 1 x 10⁻⁵ (Layton, 1987).

In a few instances where an oral LD₅₀ cannot be obtained for a chemical, the lowest toxic dose (TD_{LO}) is used instead. If a TD_{LO} is based on animal data, the "derived RfD" is estimated by multiplying the TD_{LO} (mg/kg) by a factor of 1 x 10⁻⁵. However, if TD_{LO} is based on human data, the "derived RfD" is estimated by multiplying the TD_{LO} (mg/kg) by a factor of 1 x 10⁻⁴. This is because a safety factor of 10 is usually used to compensate for the potential difference in sensitivity between laboratory animals and humans.

The maximum allowable annual average air concentration can then be determined using the following equation:

$$\text{Dose} = \frac{[\text{Air}] \times \text{BR}}{\text{BW}} \quad \text{or} \quad [\text{Air}] = \frac{\text{Dose} \times \text{BW}}{\text{BR}}$$

Where:

Dose = Maximum allowable lifetime average daily dose (as described above; mg/kg-day)

[Air] = Maximum allowable annual average air concentration (mg/m³)

BR = Breathing rate (m³/day)

BW = Body weight (kg)

Assuming an allowable lifetime average daily dose of 1×10^{-7} mg/kg-day (see above), an average adult body weight of 70 kg, and an adult daily breathing rate of 20 m³/day (U.S. EPA, 1990a), the allowable annual average air concentration equals:

$$\begin{aligned} [\text{Air}] &= \frac{1 \times 10^{-7} \text{ mg/kg-day} \times 70 \text{ kg}}{20 \text{ m}^3/\text{day}} \\ &= 3.5 \times 10^{-7} \text{ mg/m}^3 \end{aligned}$$

The second step in defining an "allowable quantity" is to relate the maximum allowable air concentration to an emission rate. For the purposes of this screening procedure, a screening-level air dispersion model approved by the U.S. EPA, SCREEN, was used. In using the SCREEN model, several conservative (i.e. assumption likely to overestimate contaminant concentrations) input parameters and assumptions were used regarding the emission condition and the location of the receptor. Conservative parameters were assigned to the source type, stack height, stack exit velocity and stack exit temperature (Appendix J). It was also conservatively assumed that the receptor was at the downwind property line of the RFP (1,800 m away from the assumed emission source) 24 hours per day, 365 days per year. Based on a unit emission rate of 1 g/sec (31,536 kg/year), the SCREEN model predicted a maximum one-hour air concentration of 271.9 µg/m³ at the receptor location under worst-case meteorological conditions. The complete results from the SCREEN model are provided in Appendix J. The maximum one-hour air concentration can then be used to develop an estimate of average annual air concentration by multiplying by 0.1 (CARB, 1987). Thus, an emission rate of 31,536 kg/yr is required to produce a maximum annual average air concentration of 27.2 µg/m³, 1,800 m away from the emission source.

This relationship between the maximum allowable annual average air concentration and the corresponding emission rate can be used to determine the emission rate for any chemical based on its SF or RfD. For example, using the previous example of a SF equal to 10 (mg/kg-day)⁻¹, the

maximum allowable annual average air concentration was shown to be $3.5 \times 10^{-7} \text{ mg/m}^3$. The corresponding emission rate can be determined as follows:

$$\frac{31536 \text{ kg/yr}}{27.2 \text{ } \mu\text{g/m}^3} = \frac{\text{Emission Rate}}{3.5 \times 10^{-7} \text{ mg/m}^3 \times 1000 \text{ } \mu\text{g/mg}}$$

or

$$\begin{aligned} \text{Emission Rate} &= \frac{31536 \text{ kg/yr} \times 3.5 \times 10^{-7} \text{ mg/m}^3 \times 1000 \text{ } \mu\text{g/mg}}{27.2 \text{ } \mu\text{g/m}^3} \\ &= 0.41 \text{ kg/yr} \end{aligned}$$

By simple proportion, if the SF of a carcinogen is decreased by a factor of 10, the corresponding "allowable" emission rate would be increased by a factor of 10. Thus, a carcinogen with a slope factor of 1 $(\text{mg/kg-day})^{-1}$ would have a maximum allowable dose equal to $1 \times 10^{-6} \text{ mg/kg-day}$, a maximum allowable air concentration equal to $3.5 \times 10^{-6} \text{ mg/m}^3$ and a corresponding allowable emission rate of 4.1 kg/yr. This relationship can be extended to noncarcinogens as well. For a chemical with a RfD of $1 \times 10^{-4} \text{ mg/kg-day}$, the maximum allowable air concentration would be $3.5 \times 10^{-4} \text{ mg/m}^3$, and a corresponding allowable emission rate of 410 kg/yr. The emission rates for carcinogens and non-carcinogens with different SFs and RfDs were similarly calculated and are presented in Tables 3-3 and 3-4.

The third and final step is to relate the emission rate of a chemical to its inventory quantity. For the purposes of this screening process, it was assumed that the inventory quantities represent 10% of the annual usage rate. This assumption is supported by a comparison of 1977 usage rates reported by the RFP in the 1980 Final Environmental Impact Statement with either 1974 or 1988/89 inventory quantities. In most cases, the inventory quantity represented 10% or more of the usage quantity (Section 3.2) making this a reasonable estimate. Lastly, it was assumed that

25% of all chemicals used are released into the environment. This is likely an overestimate for the majority of the chemicals considered, since physical state (especially for non-volatiles and insolubles), means of storage (e.g., stored in bottles or vials) and usage make 25% release unlikely. The only exception may be volatile compounds, which under certain circumstances, may be eventually released entirely to the environment.

The allowable inventory quantity of a chemical is calculated from the allowable emission rate as follows:

$$\text{Allowable inventory quantity (kg)} = \frac{\text{Allowable emission rate (kg/yr)}}{0.25 \times 10}$$

For example, if the allowable emission rate of a chemical is estimated to be 410 kg/yr, then its corresponding allowable inventory quantity would be 160 kg as shown in Table 3-3 and 3-4.

insert table 3-3

insert table 3-4

3.3.2.2.2 Drinking Water Exposure

Two drinking water sources are within 5 miles of the RFP. For the purposes of this screening process, it was assumed that chemicals from RFP could be released directly into the Great Western Reservoir. This reservoir was chosen over Standley Lake, because it is closer to the RFP, has traditionally received any plant discharges and has a smaller capacity. This is a conservative assumption, since for a given quantity of release, discharge to a smaller body of water would result in a higher water concentration. It was also assumed that chemicals were released in a single event and were fully mixed in the reservoir, although it is more likely that any discharge would be gradual and maintained over a period of time. As such, the actual chemical concentrations in the Great Western Reservoir would probably be lower than those assumed in this scenario.

The maximum allowable quantity of a chemical that can be present at the RFP without posing a potential drinking water ingestion hazard is determined in a similar manner as described above for the inhalation scenario. First, the maximum allowable dose is calculated from a defined level of risk (carcinogens) or exposure (noncarcinogens). Second, the corresponding drinking water concentration is determined using conservative exposure assumptions. Lastly, the allowable drinking water concentration is related to the maximum allowable inventory quantity. The following example illustrates each of the three steps.

As described above, the maximum allowable lifetime average daily dose for a carcinogen with a slope factor of 10 is equal to 1×10^{-7} mg/kg-day. The corresponding drinking water concentration can be determined using the following equation:

$$\text{Dose} = \frac{[\text{Water}] \times \text{IR}}{\text{BW}}$$

or

$$[\text{Water}] = \frac{\text{Dose} \times \text{BW}}{\text{IR}}$$

Where:

Dose = Maximum allowable lifetime average daily dose (mg/kg-day)

[Water] = Annual average drinking water concentration (mg/L)

IR = Water ingestion rate (L/day)

BW = Body weight (kg)

Assuming an allowable lifetime average daily dose of 1×10^{-7} mg/kg-day, an average adult body weight of 70 kg, and a water ingestion rate of 2 L/day (U.S. EPA, 1990a), the allowable annual average drinking water concentration is:

$$\begin{aligned} [\text{Water}] &= \frac{1 \times 10^{-7} \text{ mg/kg-day} \times 70 \text{ kg}}{2 \text{ L/day}} \\ &= 3.5 \times 10^{-6} \text{ mg/kg-day} \end{aligned}$$

As before, if the SF is decreased by a factor of 10, the corresponding allowable annual average drinking water concentration would be increased by a factor of 10. This relationship also applies to non-carcinogens. For a chemical with an RfD of 1×10^{-4} mg/kg-day, the allowable annual average drinking water concentration would be 3.5×10^{-3} mg/L.

The next step is to relate the allowable annual average drinking water concentration to the amount of chemical that must be released into the Great Western Reservoir at one time to achieve that concentration. According to the Rocky Flats Plant Site Final Environmental Impact Statement (DOE, 1980), the capacity of the Great Western Reservoir is 4.0×10^9 L, and over 70% of this volume of water is consumed annually. If it is assumed that the annual quantity of a chemical

released is fully mixed into Great Western Reservoir at one time, an upper limit on the annual average drinking water concentration can be determined from:

$$[\text{Water}] = \frac{\text{Released Quantity}}{\text{Volume in Reservoir}}$$

This results in the following estimate of the release quantity that will keep annual average drinking water concentration below the allowable level:

$$\text{Released Quantity} = [\text{Water}] \times \text{Volume in Reservoir}$$

Assuming an allowable annual average drinking water concentration of 3.5×10^{-3} mg/L (see above), the corresponding released quantity equals:

$$\begin{aligned} \text{Released Quantity} &= 3.5 \times 10^{-3} \text{ mg/L} \times 4.0 \times 10^9 \text{ L} \\ &= 1.4 \times 10^7 \text{ mg or 14 kg} \end{aligned}$$

Given that the water is treated as it leaves the Great Western Reservoir (e.g., alum precipitation, pH adjustment, polymer coagulation and filtration) and that the concentration of a chemical in the reservoir will be decreased due to adsorption or absorption to the sediments, biodegradation, photo-oxidation, evaporation, or dilution due to inflows and outflows, it is reasonable to assume that these processes decrease the chemical concentrations in the water by a factor of 10. Therefore, the allowable release quantity associated with a drinking water concentration of 3.5×10^{-3} mg/L is 140 kg/yr. The allowable release quantities for carcinogens and noncarcinogens with different SFs and RfDs are presented in Tables 3-5 and 3-6.

The final step is to relate the released quantity of a chemical to its inventory quantity. As described for the inhalation scenario, it was again assumed that the inventory represents 10% of the annual usage rate, and that 25% of all chemicals used are released into the environment. Therefore, for a released quantity of 140 kg/yr, the corresponding inventory quantity is equal to 56 kg. Allowable inventory quantities for carcinogens and noncarcinogens with different SFs and RfDs are presented in Tables 3-5 and 3-6.

3.3.2.3 Quantity Limit for Stage 1 Screening

As discussed in Section 3.3.1.2, an inventory quantity of 5 kg was used to eliminate some Priority 1 compounds that do not have an established SF or RfD from further consideration. The purpose of the cut-off quantity was to reduce the number of chemicals that were to be investigated for toxicity information. Given that some chemicals were eliminated without any consideration of their toxicity, it is important that the cut-off quantity be very conservative (i.e. tend to include compounds that are not a hazard rather than exclude ones that might be). The 5 kg cut-off quantity was selected using the inhalation and ingestion of drinking water exposure scenarios described above and some additional assumptions.

As stated previously, the cut-off quantity was used only for compounds not having an established SF or RfD. For those chemicals that are environmentally important and recognized as highly toxic, it is likely that the majority of them are recognized as such by the U.S. EPA and are included in the Health Effects Assessment Summary Tables (USEPA, 1990a). However, to select a cut-off quantity related to toxicity for those chemicals without a SF or RfD, oral LD₅₀s were evaluated.

insert table 3-5

insert table 3-6

A chemical with an oral LD_{50} of 10 mg/kg or below is considered extremely toxic (Klaasen, 1986). Based on a LD_{50} of 10 mg/kg, the derived RfD is equal to 1×10^{-4} mg/kg-day (Layton, 1987). Using the tables created in the previous section, the required inventory quantities associated with the inhalation and drinking water scenarios are 164 kg and 56 kg, respectively. Using the lower value of 56 kg and adding an additional safety factor of 10, the cut-off inventory quantity is 5.6 kg. Therefore, based on conservative screening exposure analysis for inhalation and drinking water ingestion and the stated release assumptions, extremely toxic chemicals that do not have an established toxicity criteria and are present in inventory quantities of 5 kg or less are unlikely to pose an off-site health hazard.

3.3.2.4 Comparison of Actual with Allowable Inventory Quantities

Chemicals on the Hazardous Chemicals List are separated into two groups, carcinogens and noncarcinogens. Benzene will be used as an example to show how carcinogens are evaluated in this screening process. According to EPA's HEAST document (U.S. EPA, 1990a), benzene has a SF of 2.9×10^{-2} (mg/kg-day) $^{-1}$ for both oral and inhalation exposures. Note that, for some carcinogens, the SF for oral and inhalation exposure pathways may not be the same and the appropriate SF should be used for the particular exposure pathway.

For the inhalation scenario, the closest SFs to 2.9×10^{-2} (mg/kg-day) $^{-1}$ listed in Table 3-3 are the entries for 0.01 and for 0.1 (mg/kg-day) $^{-1}$. As this is a screening exercise, a carcinogen with a higher SF, i.e., 0.1 (mg/kg-day) $^{-1}$, is conservatively chosen as the reference to evaluate benzene. According to the table, the required inventory quantity that a chemical with a SF of 0.1 (mg/kg-day) $^{-1}$ must have to pose a potential off-site health hazard is estimated to be 16 kg. The inventory quantities of benzene in 1974 and 1988/89 are 6.0 and 42.5 kg, respectively. The higher inventory quantity of benzene is used for this evaluation. The ratio of the inventory quantity to the allowable inventory quantity for benzene is therefore equal to $42.5/16$ or 2.7.

Similarly, the potential for benzene to pose a drinking water hazard is evaluated using Table 3-5. As explained above, the SF table entry of $0.1 \text{ (mg/kg-day)}^{-1}$ is used, and the 1988/89 reported inventory quantity is chosen to evaluate benzene. The ratio of the inventory quantity to the allowable inventory quantity for benzene equals $42.5/5.6$ or 7.6 , which is a higher value than that obtained from the inhalation scenario. The higher of the two calculated ratios of allowable quantity for the two pathways is used to determine the need for subsequent evaluation of the chemical.

The evaluation of noncarcinogens is similar to carcinogens, except RfDs are used instead of SFs. 1,1,1-Trichloroethane can be used to illustrate the evaluation of noncarcinogens. According to the HEAST (U.S. EPA, 1990a), 1,1,1-trichloroethane has an inhalation RfD of 0.3 mg/kg-day and an oral RfD of 0.09 mg/kg-day . Using Table 3-4 to evaluate the chemical's inhalation hazard, the required inventory quantity is $160,000 \text{ kg}$. Similarly, using Table 3-6 to evaluate the chemical as a drinking water health hazard, the required inventory quantity is $5,600 \text{ kg}$. The inventory quantity for 1,1,1-trichloroethane in the 1974 inventory is $22,763 \text{ kg}$. The quantity ratio of the chemical for inhalation exposure is equal to $22,763/160,000$ or 0.14 and its quantity ratio for drinking water exposure is equal to $22,763/5,600$ or 4.1 . As explained above, the higher value of the two quantity ratios is used to determine the need for subsequent evaluation of the chemical. Therefore, 1,1,1-trichloroethane has a quantity ratio value of 4.1 .

Each chemical on the Hazardous Chemicals List was similarly evaluated to determine its quantity ratio. The result of this screening exercise is presented in Table 3-7 and in Appendix K. There are 41 chemicals with a quantity ratio greater than 1 based on the combined 1974 and 1988/89 inventories, and 4 chemicals based on chemicals unique to the 1974 inventory. Together, these chemicals comprise the potential chemicals of concern for the RFP based on Stage 2 of this screening analysis.

3.3.2.5 Evaluation of Reproductive and Developmental Toxicants

In Stage 1 screening, 12 potential reproductive and developmental toxicants were identified (Appendix E). Based on health effects unrelated to reproductive or developmental effects, five of these toxicants: ethylene oxide, hexachlorobenzene, lead compounds, mercury compounds and Aroclors (PCBs) were identified as chemicals of potential concern in Stage 2 screening.

The remaining seven toxicants are evaluated in this section using an approach similar to that used for noncarcinogenic chemicals with RfDs in Stage 2 screening. Since there is no official health criterion for evaluating reproductive hazard of these chemicals, a reproductive screening dose is developed for each of them.

The majority of screening doses derived for this analysis are based on reproductive toxicity information from animal testing. The lowest observable effect level (LOEL) or no observable effect level (NOEL) is commonly used to define the dose associated with minimal or no adverse health effects in the tested animals. In the derivation of reproductive screening dose for humans, the NOEL is preferred over LOEL when both values are reported. However, when only the LOEL is available for a chemical, the standard practice is to divide the LOEL by 10 to estimate the NOEL.

The reproductive screening dose for a chemical is determined for the purposes of this analysis by dividing the animal NOEL by a safety factor of 100. The safety factor of 100 includes a safety factor of 10 to allow for potentially higher sensitivities of humans

insert table 3-7

insert table 3-7

compared to the experimental animals and another factor of 10 to allow for differences in sensitivities among individuals.

The LOEL is reported for humans for one of the chemicals. In this case, the reproductive screening dose is determined by dividing the human LOEL by a factor of 100. This includes a safety factor of 10 to estimate the NOEL and another factor of 10 to allow for differences in sensitivities among individuals.

Table 3-8 identifies the reproductive screening dose for each of the seven chemicals evaluated in this section and the reproductive toxicity information used to derive them.

An allowable quantity for each chemical is determined using the same methodology described in Section 3.3.2.2 using the reproductive screening dose. In most cases the drinking water exposure scenario generates a lower allowable quantity and is therefore the basis for the evaluation. However, for carbon monoxide, the inhalation exposure scenario is the most restrictive pathway and is used to determine the allowable quantity. Table 3-9 identifies the allowable quantities for each of the seven reproductive toxicants.

The potential reproductive health impact to off-site individuals for each chemical is evaluated by calculating its quantity ratio. This ratio is calculated by dividing the inventory quantity of a chemical by its allowable quantity. For the purpose of this screening process, if the quantity ratio of a chemical is greater than 1, it poses a potential reproductive hazard to off-site individuals. If the ratio is less than 1, then it is unlikely for the chemical to have posed a reproductive hazard to off-site individuals.

As shown in Table 3-9, all of the chemicals evaluated have a quantity ratio below 1. Therefore based on this screening evaluation, it is unlikely that these chemicals have posed a reproductive hazard to off-site individuals.

insert table 3-8

insert table 3-9

3.3.2.6 Multipathway Exposure Considerations

Indirect pathways of exposure may contribute significantly to the total dose received by a receptor for some chemicals. Such indirect exposures result from chemical deposition on crops, soils and surface water and transmission to the receptor through vegetables, fish, meat, dairy products and mother's milk. Chemicals for which indirect exposures are considered important have been identified by the California Air Pollution Control Officers Association (CAPCOA, 1990) and these chemicals are listed in Table 3-10. All chemicals identified on the table, with the exception of nitrosamines, are already included in the Potential Chemicals of Concern List generated by the screening process (Table 3-7).

Three nitrosamines were identified in the 1988/89 RFP inventory: N-nitroso-di-n-propylamine (0.001 kg), N-nitroso-diphenylamine (0.005 kg) and N-nitroso-phenylamine (0.01 kg). The only nitrosamine identified in the 1974 inventory is N-nitroso-diphenylamine (0.02 kg).

Based on information in the HEAST (U.S. EPA, 1990a), N-nitroso-di-n-propylamine has an oral SF of $7 \text{ (mg/kg-day)}^{-1}$ and N-nitroso-diphenylamine has an oral SF of $0.005 \text{ (mg/kg-day)}^{-1}$. No inhalation toxicity criterion was found for these 2 nitrosamines. N-nitroso-phenylamine is not listed in Table 3-10 and no oral or inhalation toxicity criterion was found for this chemical.

If the two nitrosamines having SFs are subjected to Stage 2 screening for drinking water exposure, the ratios of the inventory quantities to the allowable quantities for N-nitroso-di-n-propylamine and N-nitroso-diphenylamine are 0.018 and 8.9×10^{-5} , respectively. Based on its quantity ratio, it is unlikely that N-nitroso-diphenylamine would pose an off-site health hazard even taking the potential multi-pathway exposures into account.

insert table 3-10

The quantity ratio of N-nitroso-di-n-propylamine is less than two orders of magnitude below unity and could therefore be of potential concern if multipathway exposures contribute to the off-site dose. N-nitroso-di-n-propylamine should be considered for inclusion in the list of potential chemicals of concern.

3.3.2.7 Strengths and Weaknesses of Stage 1 and Stage 2 Screening

Given the complexity of identifying a limited set of potential chemicals of concern from a list of more than 8,000 entries, it is to be expected that any selection process would contain both strengths and weaknesses. The selection process utilized here is no exception. However, this process has been conservatively designed in order to minimize the possibility of eliminating any chemicals that could possibly pose a health hazard to an off-site individual. The strengths and weaknesses of Stage 1 and Stage 2 screening are listed in Table 3-11.

Concerns have been raised with regards to potential synergistic effects between chemicals and transformation of one chemical to another. These concerns are discussed in the following sections.

3.3.2.8 Chemical Synergism

A synergistic effect is when the combined effect of two chemicals is much greater than the sum of the effect of each agent given alone. A closely related effect is potentiation, which occurs when a noneffective chemical increases the magnitude of the effect produced by another chemical.

There are numerous instances where synergism or potentiation have been observed in laboratory animals. However, most of these exposure conditions are very different from

insert Table 3-11

insert Table 3-11

human experience, such as laboratory animals are usually given 2 pure chemicals in relatively high concentration and for a short period of time. Humans are exposed to hundreds of chemicals in very low concentrations for 60-70 years. Chemicals are also often administered to the test animals in a way that has no relevance to humans exposure conditions.

Furthermore, most screening tests for interactions employ simultaneous exposure. This approach may miss some potential interactions, such as when the two agents being evaluated affect the same cellular mechanism in causing a toxic effect but they may have a different time of onset. More specifically, dermal exposure to an initiator like benzo[a]pyrene must take place before the exposure to the promoter (e.g., croton oil or phorbol esters) for the interaction to occur. Therefore, while animal results can suggest the potential interaction of multiple chemical exposures and give insights to the mechanism of interaction, direct extrapolation of animal data to humans is difficult.

Another approach is to conduct epidemiologic studies based on human exposure experiences. There are several reported potential synergistic interactions involving tobacco smoking or alcohol drinking:

- asbestos and smoking
- radon gas and smoking
- alcohol drinking and smoking
- carbon disulfide and drinking
- some chlorinated aliphatics and drinking

The interaction between tobacco smoking and occupational exposures in the causation of lung cancer has been a highly researched area. In 1968, Selikoff et al. first reported there is a strong synergistic effect between asbestos and smoking. Other researchers studied asbestos factory

workers and revealed that both additive and multiplicative models fit the data, with the multiplicative model fitting slightly better.

It is important to note that even though smoking and asbestos are among the best investigated interactions, the data are still insufficient for a clear-cut determination of the nature of their interaction (additive vs multiplicative) (Calabrese, 1991).

A considerable number of occupational epidemiologic studies have examined the possible interaction of smoking and radon exposure on the incidence of lung cancer. While the result of several smaller studies supported additive, submultiplicative and multiplicative models, the largest study reported by Whittemore and McMitlan in 1983 supported a multiplicative interaction (Calabrese, 1991).

The potential synergistic interaction of alcohol consumption and other chemical exposures in causing cancer is highly controversial and not as well studied. Rothman (1975) reported that heavy drinkers have a risk of 2 to 6 times greater than nondrinkers, depending on the degree of concomitant smoking activity. However, in many instances, considerable controversy persists, and data from different studies often conflict with each other.

Studies have indicated that individuals exposed to alcohol and carbon disulfide or alcohol and carbon tetrachloride are more susceptible to liver damage. Both carbon disulfide and carbon tetrachloride require bioactivation by certain liver enzymes to exert their liver toxicity. Alcohol consumption is known to increase the activity of these liver enzymes and therefore enhance the toxicity of these two chemicals.

Almost all of the synergism studies discussed above are based on occupational exposures. However, in most environmental exposures, the concentration of the chemical under consideration

is usually many times lower than in an occupational setting. It is argued that when the chemical dose is very low, synergistic effect or multiplicative effect is virtually indistinguishable from additive effect. This is one of the reasons why the U.S. EPA recommends summing of cancer risks when evaluating the health effects of more than one carcinogen. The agency has also developed a hazard index approach to evaluate the noncarcinogenic effect of chronic toxicants. The hazard index is equal to the sum of the ratios of the subthreshold exposures to acceptable exposures. The following equation is presented in the Risk Guidance for Superfund (Volume 1), human health evaluation manual (USEPA, 1989).

$$\text{Hazard Index} = E_1/\text{RfD}_1 + E_2/\text{RfD}_2 + \dots + E_i/\text{RfD}_i$$

Where :

E_i = exposure level (or intake) for the i^{th} toxicant;

RfD_i = reference dose for the i^{th} toxicant; and

E and RfD are expressed in the same units and represent the same exposure period (i.e. chronic, subchronic or short-term). It is also recommended that this equation only be applied to chemicals that produce similar toxic effects or have similar mechanisms of action.

Clearly the topic of synergism is an area of investigation for scientists where there is still much to be learned. Current practice argues for the summation of hazards from exposure to multiple chemicals having similar toxic endpoints. The screening process employed in this analysis incorporates numerous conservatisms that greatly overstate the potential for hazard from an individual chemical for the purposes of identifying compounds of potential concern. As estimated doses and risks from chemicals and radionuclides are quantified later in the project it will be appropriate to consider the additivity of these risks. However, for the purposes of identifying chemicals for further study on the project it is believed that the screening process is sufficiently

conservative such that potential hazards are not significantly understated even if synergistic effects were to occur.

3.3.2.9 Chemical Transformation

The consideration of chemical transformation has also been identified as a concern for identifying potential hazards. The screening process evaluates the potential hazards from chemicals that are used in various plant processes and released to the environment. The concern is that chemicals could be transformed as a result of processing or degradation in the environment to more toxic compounds. These concerns, like synergism, touch on a very complex topic for which there are no simple answers.

The identification of chemicals that are byproducts of processes performed at the plant require a fairly detailed knowledge of the chemical processes at the plant. Detailed waste stream characterization reports have been prepared for the plant that identify a large number of chemicals from hundreds of waste streams that are present in widely varying concentrations down to trace concentrations. These waste stream reports present an extremely complex picture of individual process liquid streams. As the project proceeds, one objective is to develop an understanding of the basic plant processes, and in turn to develop an understanding of any major byproducts of these processes that have been released to the environment.

The scientific community is in an early stage in understanding how released pollutants interact with other chemical and physical components in the environment. Nevertheless, we have developed some understanding about transformation of some major groups of chemicals and well-known chemicals in the environment. In general, substances can be divided into two categories, refractory and non-refractory substances, based on their relative susceptibility to chemical transformation in the environment.

The refractory substances tend to retain their chemical composition, physical properties and toxicity in the environment for a long period of time. Examples are: metals, polychlorinated aromatics and chlorinated aliphatics.

The non-refractory substances have a relatively short life-time in the environment. They either contain reactive functional groups that react with other environmental components, or are often degraded by microorganisms in the environment. Many highly toxic chemicals contain reactive functional groups e.g., ethylene oxide, propylene oxide, and acrylamide that exert their toxic effects through the interaction between their reactive functional groups and biological materials. Thus when the reactive functional groups are changed through reaction or conjugation with other environmental materials, they also become less toxic.

Strong acids (hydrochloric acid, sulfuric acid and nitric acid) and strong bases (ammonia, sodium hydroxide and potassium hydroxide) normally do not retain their strength for long in either soil or natural water. Organic and inorganic matters in these media have substantial buffering power and tend to resist drastic changes in pH. However, if the quantity of acid or base release is large and last over a long period of time, the buffering capacity of the system can be overwhelmed and a change of pH observed.

Chemicals with a strong oxidizing or reducing power usually do not have a long half-life in the environment. They tend to react with other oxidants or reductants in the environment to attain a more stable state or form. For example, hexavalent chromium is reduced to trivalent state in natural waters by Fe (II), dissolved sulfides, and organic compounds with sulfhydryl groups (USEPA, 1979). Theoretically, MnO_2 in soil can oxidize trivalent chromium to the hexavalent state, however, in reality this process is seldom observed in the environment. This is because at pH greater than 5, trivalent chromium quickly precipitates due to the formation of the insoluble

hydroxide or oxide (USEPA, 1979). As a result, a major fraction of trivalent chromium is immobilized and separated from oxidizing agents in the environment.

There are numerous types of microorganisms in soils, lakes, rivers and seas. Each type is capable of using a particular type of chemicals as a nutrient and source of energy. Together, they can breakdown a wide range of chemical substances to smaller and less toxic molecules. Most of the organic compounds included in the potential chemicals of concern list can be biodegraded within a reasonable period of time. There are a few exceptions: hexachlorobenzene, aroclors (PCBs), polyaromatic hydrocarbons and chlorinated short chain aliphatics. These chemicals are rather resistant to biodegradation and may persist in the environment for a long period of time. Chlorinated short chain aliphatics like chloroform, trichloroethene and methylene chloride do not stay in exposed surface water or soil. They tend to volatilize from the soil and aquatic systems to the atmosphere. Once in the troposphere, they are photo-oxidized relatively rapidly with an atmospheric lifetime ranging from several days to a few months.

There are examples where microorganisms increase the toxicity of a chemical through their activities. Conversion of mercury to dimethylmercury by anaerobic bacteria is a good example. In this case, the metabolic product is more mobile and toxic than the parent substance.

Chemical reactions (transformation) are generally favored by a high concentration of reacting components and a high temperature. Except for some highly reactive reagents, ambient temperature is usually too low for chemical reactions to take place. Due to dilution and dispersion, contaminant concentrations in the environment are usually very low, in the parts per million to parts per thousand ranges. As a result, it is rare to observe chemical reactions taking place in the environment to an appreciable extent. However, when sufficient energy is given to chemicals in the environment, reactions do take place. One well-known example is the absorption of solar energy by certain organic compounds in air or water to form reactive species or free radicals.

These intermediates can then decompose or react further with other chemicals in the environment to form products which may be more or less toxic than the parent compounds. Polycyclic aromatic hydrocarbons absorb solar radiation at wavelengths above 300 nm and undergo photo-oxidation. For example, benzo[a]pyrene, benzo[a]anthracene and anthracene have photo-oxidation half-lives in water of 1.2, 3 and 0.6 hr, respectively (USEPA, 1979).

Some reactive chemicals may react spontaneously with water or moisture in the environment. For example, potassium and sodium metal react with water to form hydroxides and hydrogen gas. Aluminum sulfide reacts with water to form aluminum hydroxide and hydrogen sulfide gas.

While a number of factors determine whether a compound is likely to pose a hazard, toxicity and quantity are the key considerations. Given the very conservative screening performed for the selection of chemicals of concern, only in the case where plant processes result in the transformation of large amounts of a chemical to a much more toxic chemical is the selection scheme used for Task 2 likely to exclude an important chemical. Those chemicals that are identified as being of potential concern will be studied in detail to determine their use at the plant and their ultimate fate including transformation at the plant or in the environment. While there is no efficient method of identifying whether important transformation products that should be the subject of further study are formed at this point in the project, subsequent project investigations will continue to seek information suggesting the need to consider additional chemicals as a result of the transformation.

3.3.3 Stage 3 Screening

Stage 2 screening identified 46 potential chemicals of concern. If sufficient quantities of these chemicals were released, they might adversely affect the health of off-site individuals. In Stage 3 screening, these chemicals are individually evaluated to determine their likelihood and relative

quantity of release based on their actual storage and normal usage. The route of release and environmental fate of some chemicals are also evaluated for their potential to result in health impacts.

The 46 potential chemicals of concern are divided into two groups based on their largest reported quantities in either the 1988/89 or 1974 inventories. Chemicals in the first group have inventory quantities below 100 kg. These chemicals are believed to be mainly used in research laboratories and are not involved in production operations. Chemicals in the second group have inventory quantities above 100 kg, and are probably used in production. Tables 3-12 and 3-13 presents the two groups of potential chemicals of concern.

3.3.3.1 Group One: Chemicals with Inventory Quantities less than 100 kg

Twenty-two potential chemicals of concern belong to this group. Most of the chemicals in this group are located and used in laboratories. Their annual usage is probably not much higher and in some cases much less than the inventory quantities. Since these are not production chemicals, the assumption used in Stage 2 screening that 25% of the annual usage quantity was released into the environment is also probably too conservative. To confirm usage, likelihood of release and quantity of release of these chemicals, the following information was obtained from personnel working at the RFP:

insert table 3-12

insert table 3-13

- verification of inventory quantities as being consistent with those reported in 1988/89,
- verification of storage location,
- characterization of normal usage,
- characterization of disposal practice, and
- estimated release.

The information that was obtained is summarized in Appendix L. The location and quantity information reported in the inventory were confirmed for most of the chemicals. A majority of the chemicals are no longer used or have a very low annual usage rate. For those chemicals having annual usage rates greater than the inventory quantities, their releases to the environment are estimated to be minimal. Based on the usage and release information provided in Appendix L, it is unlikely for the listed chemicals to pose a significant off-site health hazard. Therefore limited use laboratory chemicals are not included in the Stage 3 chemicals of concern list.

It is possible that some of the chemicals listed in Appendix L were used differently in the past. Table 3-14 compares the inventory quantities of the chemicals that are reported in both 1988/89 and 1974. The inventory quantities of many chemicals are higher in the 1974 report than in the 1988/89 report. However, most of the chemicals are listed below 10 kg. This indicates that these chemicals were probably also used in laboratories in 1974. There are three exceptions: benzene, hydrazine and sodium nitrite were reported in quantities in excess of 10 kg in 1974.

Sodium nitrite is reported to have an inventory quantity of 10 kg in 1988/89 and 63 kg in 1974. It can be used as a fertilizer or food preservative. With its relatively low toxicity and small inventory quantity, it is unlikely that sodium nitrite posed a significant health

insert table 3-14

hazard to off-site individuals. Therefore, sodium nitrite is not included in the chemicals of concern list.

Benzene is a human carcinogen and hydrazine is an animal carcinogen. These two chemicals were reported in larger quantities in the past and might have been used in production. They are included in the chemicals of concern list.

Benzidine and propylene oxide are only reported in the 1974 inventory. As they are no longer used in RFP, their usage and disposal could not be readily characterized. Benzidine is a human carcinogen and propylene oxide is an animal carcinogen. Since there is no usage or release information available for these two chemicals, they are included in the chemicals of concern list.

Aroclors or polychlorinated biphenyls (PCBs) were reported to have an inventory quantity of 0.12 kg in the 1988/89 report. It is believed that PCBs might have been used in transformers in much greater quantities. However, any environmental release of PCBs from transformers would more likely be related to accidents and spills than to routine plant operation. For this reason, PCBs are not included in the chemicals of concern list, but are recommended to be evaluated if found to be associated with any accidents or incidents. Also, should environmental contamination by PCBs be confirmed as a potential concern, sediment and soil sampling would be the most efficient way of evaluating the hazards associated with this persistent chemical.

There are four pesticides on the potential chemicals of concern list. Chloranil, vaponite 2 insecticide and diazinon have inventory quantity less than 100 kg. In the 1974 inventory, bromacil was reported to have an inventory quantity greater than 100 kg. It is known that there are many more pesticides and herbicides that have been used at the RFP, however, no information about the quantities used and method of application have been identified at this point in the project.

Furthermore, it is known that outside contractors were hired to apply pesticides and herbicides at the RFP and that materials used by these contractors would not be reported in the plant inventories.

Pesticides and herbicides are likely to have been applied throughout the history of the plant with the specific product used and the nature of the application varying over time as different compounds came into and went out of use. In many cases contractors or entities other than the plant operator were responsible for the application of these materials. The use of these materials were not unique to the plant and are not directly related to the production processes at the plant. However, the historic presence of these compounds in holding ponds at the site has been the subject of public concern and for this reason will be addressed by this project. Pesticides and herbicides have therefore been retained as a group of compounds that need to be addressed further by the study as chemicals of concern.

3.3.3.2 Group Two: Chemicals with Inventory Quantities Greater than 100 kg

There are 24 chemicals in group two. Most of these chemicals are reported in large inventory quantities and are probably used in production. These chemicals have been separated into 4 subgroups based on the similarity of their chemical and physical properties:

- acids and bases
- elements
- chlorinated hydrocarbons
- others

3.3.3.2.1 Acids and Bases

The following six acids and bases are on the potential chemicals of concern list from Stage 2 screening: sodium hydroxide, potassium hydroxide, perchloric acid, hydrochloric acid, phosphoric acid and ammonia. Sulfuric acid, nitric acid and hydrofluoric acid were listed on List B because they have neither an established health criterion nor an oral LD₅₀. In both the 1974 and 1988/89 inventory reports, these three acids are listed in large inventory quantities and are probably used in production. The potential health impacts of these three acids are discussed together with the other acids and bases on the potential chemicals of concern list.

In general, when strong acids and bases are released into soil or surface water, they are likely to be quickly diluted, neutralized and buffered by natural components in the environment. It is expected that if the acids and bases discussed in this section were released into the soil, groundwater or surface water, their concentrations and strengths would decrease drastically with increasing distance from the source. Since the closest community is about 1 mile away from the RFP, these chemicals are not likely to pose a significant health impact to off-site individuals.

Based on the 1988/89 inventory report and other documents, it is apparent that most of the acids and bases used at the RFP are destroyed on-site. For example, the major use of potassium hydroxide identified in the inventory is for neutralization (Appendix M). Potassium hydroxide is used to neutralize chemicals (like nitric acid) in reaction vessels, tanks and fume scrubbers. In all these processes, potassium hydroxide is consumed, rendering it less toxic. According to the 1988/89 inventory report, about 70% of the total inventory quantity of potassium hydroxide is used for these processes. In other words, only about 30% of the potassium hydroxide reported in the inventory is available for potential release.

Similarly, sodium hydroxide is used in regenerating demineralizer, acid neutralization, water treatment and pH adjustment (Appendix M). According to the 1988/89 inventory report, about 90% of the total inventory quantity of sodium hydroxide is used for these operations.

Ammonia is used to neutralize nitric acid and precipitate uranium and plutonium oxides (APEN, 1990). However, it is not clear how much ammonia is neutralized on-site.

According to the 1988/89 inventory report, about 80% of sulfuric acid is neutralized on site (Appendix M). It is mainly used to regenerate the demineralizers, treat water in cooling towers, control the pH of cooling water and precipitate chemicals. Therefore, only about 20% of the sulfuric acid reported is available for potential release.

Based on the Air Pollution Emission Notices (APEN, 1990), most nitric acid used in building 771 is either neutralized or evaporated and scrubbed with bases on-site. These processes effectively convert nitric acid into salts of low toxicity and drastically reduce the quantity of nitric acid available for release. The APEN estimated that in 1988, about 59,890 kg of nitric acid was used building 771 and a majority of the acid is neutralized on-site.

Acids and bases are skin and respiratory irritants. They generally cause acute health effects and do not have cumulative toxicities. Since any liquid effluents are likely to be buffered in the environment, only air emissions pose some potential for transport of these compounds. Sodium hydroxide, potassium hydroxide, phosphoric acid, perchloric acid and sulfuric acid are not volatile. The only mechanism of potential transport in air is in the form of mist and aerosols. It is unlikely that sufficiently large quantities of these acids or bases could be aerosolized to pose a significant health hazard to off-site individuals. Therefore, sodium hydroxide, potassium hydroxide, phosphoric acid, perchloric acid and sulfuric acid are not included in the chemicals of concern list.

Hydrochloric acid, ammonia, hydrofluoric acid and nitric acid in high concentrations can give off fumes and vapors even at room temperature and could be transported off-site. Table 3-15 lists the air concentrations of hydrochloric acid and ammonia at the RFP fence line predicted by the air dispersion model described in the Stage 2 screening. The estimated allowable quantities and the quantity ratios of these 2 chemicals are also presented. Based on the inhalation exposure scenario, the quantity ratio of hydrochloric acid is 0.81. Therefore, hydrochloric acid is unlikely to pose a health hazard to off-site individuals and has not been included as a chemical of concern.

The predicted screening concentration of ammonia at the fence line is 2.1 mg/m^3 . This predicted air concentration is higher than the U.S. EPA reference concentration of 0.36 mg/m^3 (USEPA, 1990a). However, this reference concentration is not based on adverse health effects, but rather on the odor threshold of humans. An ammonia odor would have been detected off-site at concentrations well below those associated with a health hazard if significant ammonia releases were occurring. Therefore, ammonia is not included in the chemicals of concern list.

Hydrofluoric acid is a strong irritant and highly corrosive. Most of the hydrofluoric acid used at the RFP is in gaseous form and almost 100% pure. It is mainly used and consumed in the hydrofluorination process in Building 771 (APEN, 1990). According to the APEN report, the annual release rate of hydrofluoric acid from this building is estimated to be about 1,000 kg/year. Hydrofluoric acid dissolved in water is also used in other buildings for plating, cleaning and etching of metal and glass parts. However, the quantities of hydrofluoric acid used in these operations are considered insignificant when compared with the hydrofluorination process.

insert table 3-15

Using the estimated release rate of 1,000 kg/year and the air dispersion model described in the Stage 2 screening, the concentration of hydrogen fluoride in air at the fence line is estimated to be 8.6×10^{-4} mg/m³. According to ACGIH (fifth edition), the occupational ceiling limit for hydrogen fluoride is 2.5 mg/m³; which is about 2,900 times higher than the predicted fence line air concentration. This margin of safety should be sufficient to cover the uncertainties in the estimation of annual usage rate and release quantities and still be health protective for sensitive and susceptible human subpopulations. Hydrofluoric acid is not included in the chemicals of concern list.

Large quantities of nitric acid are used at RFP. Many production operations involving the use of nitric acid have built-in systems to scrub the exit gas stream before release. Waste nitric acid solutions are normally treated on-site by neutralization. Nevertheless, it was estimated that in 1988 1,952 kg of nitric acid was released as fugitive emissions and 38,590 kg was released through stack emissions (Rockwell International, 1989). Thus, the total annual release rate is estimated to be about 40,542 kg/year. Based on the air dispersion model described in the Stage 2 screening, the predicted concentration of nitric acid in air is 3.5×10^{-2} mg/m³. According to ACGIH (1990-1991), the occupational 8-hour exposure criterion (threshold limit value) for nitric acid is 5.2 mg/m³; which is about 148 times higher than the predicted fence line air concentration. As shown in Table 3-1, annual usage of nitric acid in 1977 is about 41 times greater than the 1974 inventory quantity. Therefore, it is felt that this margin of safety may not be sufficient to cover the uncertainty in the estimated release quantity of nitric acid and to protect the health of susceptible human subpopulations. For this reason, nitric acid is included in the chemicals of concern list.

3.3.3.2.2 Elements

There are eight elements on the potential chemicals of concern list. Three of them are essential nutrients: manganese, cobalt and chromium (trivalent state). These elements in low concentrations are required by the human body to maintain good health. However, they may produce adverse health effects when the average daily intake exceeds a certain level.

In Stage 2 screening, a derived RfD was calculated for cobalt by dividing its LD₅₀ by a factor of 100,000. This approach is appropriate for chronic toxicants but is probably too conservative for essential nutrients like cobalt. The human daily dietary intake of cobalt is estimated to be about 0.1-0.25 mg/day (California State Water Resources Control Board, 1963). Using the exposure scenarios described in Section 3.3.2.2, concentrations of cobalt in air and water are calculated. The average daily dose of cobalt received by a maximally exposed individual through inhalation and drinking water ingestion are 0.029 mg/day and 0.085 mg/day, respectively (Table 3-16). These doses are lower than the daily dietary intake level and are unlikely to pose a health hazard to off-site individuals. Table 3-16 compares the predicted cobalt screening air concentration at the RFP fence line with the occupational air standard set by American Conference of Governmental Industrial Hygienists (ACGIH, 1990-1991). The predicted air concentration is about 35 times lower than the occupational air standard, and since the air dispersion model neglects the effect of deposition, this predicted air concentration is likely to be much greater than the actual concentration. For this reason, cobalt is not included in the chemicals of concern list.

Manganese is also an essential nutrient for humans. The safe and adequate dietary allowance of manganese recommended for an adult is 10 mg/day (California State Water Resources Control Board, 1963). Using the exposure scenarios described in section

insert table 3-16

3.3.2.2, concentrations of manganese in air and water are predicted. The average daily dose of manganese received by a maximally exposed individual through drinking water ingestion is 0.33 mg/day (Table 3-16). As this dose is below the dietary allowance, manganese compounds are not considered to pose a drinking water health hazard to off-site individuals. However, the health criterion for manganese through inhalation is about 660 times more stringent than that for the oral route. U.S. EPA recommends manganese in air not to exceed 0.001 mg/m³ (U.S. EPA, 1990a), which is about 5 times lower than the predicted manganese screening air concentration at the RFP fence line. Nevertheless, manganese is not likely to pose a significant health hazard to off-site individuals because of the following reasons:

- the predicted manganese air concentration is at the fence line and most residential and industrial areas are much farther away from the facility;
- manganese and manganese compounds are not volatile and can only be dispersed through air as particulates. The screening air model does not take into account the effect of deposition which would reduce downwind air concentration of manganese;
- multipathway exposure to manganese is not a concern. As explained above, oral route of exposure to the predicted level of manganese does not pose a health hazard.

The manganese air concentration is also compared with the occupational air standard set by American Conference of Governmental Industrial Hygienists (ACGIH, 1990-1991). As shown in Table 3-16, the predicted air concentration is about 1,000 times lower than the occupational air standard. Manganese is not included in the chemical of concern list.

Cadmium, nickel, chromium, beryllium and lead are potential animal and human carcinogens. Mercury is a neurotoxin and a potential reproductive and developmental toxicant. These metals are found in relatively large inventory quantities at the RFP and are probably used in production. If significant quantities of these chemicals were released into the environment, they could adversely

affect the health of off-site individuals. These six metals are included in the chemicals of concern list.

3.3.3.2.3 Chlorinated Aliphatics

There are six chlorinated aliphatics on the potential chemicals of concern list that belong to this group. They are methylene chloride, tetrachloroethylene, chloroform, carbon tetrachloride, trichloroethene and 1,1,1-trichloroethane. With the exception of 1,1,1-trichloroethane, they are all suspected animal or human carcinogens. If significant quantities of any of these chemicals were released into the environment, they might adversely affect the health of off-site individuals. They are all included in the chemicals of concern list.

3.3.3.2.4 Others

There are three chemicals in group two that have not yet been evaluated. They are butadiene, formaldehyde and ethylene oxide. Butadiene and ethylene oxide are reported only in the 1974 inventory. There is no specific information about the usage and storage location of these two chemicals. All three chemicals are suspected animal or human carcinogens that may have been used in production. If these chemicals were released in sufficient quantities, they might have posed a health impact on off-site individuals. Therefore, butadiene, formaldehyde and ethylene oxide are included in the chemicals of concern list.

3.3.3.3 Result of Stage 3 Screening

A total of 20 chemicals and the pesticide/herbicide group remain on the chemicals of concern list after Stage 3 screening (Table 3-17). A brief discussion of the usage, environmental fate and acute and chronic toxicity of each chemical is presented in Appendix N. The chemicals that were evaluated in Stage 3 but not selected are identified on List D (Table 3-18).

4.0 CONCLUSIONS

The objective of Task 2 was to identify those materials that have been present at the Rocky Flats Plant which could have exposure off-site populations to health hazards during the operating history of the plant. Using both qualitative and quantitative screening criteria a number of compounds that could potentially have been associated with off-site impact from normal operations have been identified for further detailed study by the project. The compounds of concern which will be the subject of further study include the radionuclides listed in Table 3-19 and the chemicals listed on Table 3-17.

insert table 3-17

insert table 3-18

insert table 3-19

5.0 REFERENCES

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APPENDIX A

**RADIOACTIVE MATERIALS
AT THE ROCKY FLATS PLANT**

APPENDIX B

RADIONUCLIDE MONITORING REPORTS REVIEWED

APPENDIX C

**COMPARISON OF INVENTORY QUANTITIES:
1974 VS. 1988/89**

APPENDIX D

SUMMATION OF INVENTORY QUANTITIES

APPENDIX E

**REPRODUCTIVE AND
DEVELOPMENTAL TOXICANTS**

APPENDIX F

LIST A CHEMICALS

APPENDIX G
HAZARDOUS CHEMICALS LIST

APPENDIX H

LIST B CHEMICALS

APPENDIX I

ADJUSTMENTS TO INVENTORY QUANTITIES

APPENDIX J

SCREEN MODEL PRINTOUT

APPENDIX K
RESULTS OF STAGE 2 SCREENING

APPENDIX L

**USAGE AND ESTIMATES OF RELEASE
OF GROUP ONE CHEMICALS**

APPENDIX M

USE OF POTASSIUM HYDROXIDE, SODIUM HYDROXIDE AND SULFURIC ACID AT ROCKY FLATS FACILITY

APPENDIX N

**USAGE, ENVIRONMENTAL FATE, ACUTE
AND CHRONIC TOXICITY OF THE CHEMICALS OF CONCERN**

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